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Science and Technology in China's Modernization

National Intelligence Estimate

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NIE 13-7/2-86/I

SCIENCE AND TECHNOLOGY IN CHINA'S MODERNIZATION

VOLUME I—KEY JUDGMENTS AND DISCUSSION

Information available as of 25 June 1986 was used in the preparation of this Estimate, which was approved by the National Foreign Intelligence Board on that date.

CONTENTS

SCOPE NOTE

The United States, as a matter of policy, supports the modernization of China. The principal assumptions underlying this policy are that a more modernized China will be more open to Western ideas and influence, will develop a larger stake in global stability, will be less prone to act in a destabilizing manner, and will be better able to withstand pressures from the USSR. At the same time, Chinese leaders believe that advances in science and technology are critical to modernization. Furthermore, they conclude that the success of their modernization programs will depend to a very large extent on how effectively they can acquire and master foreign technology. [redacted]

This Estimate deals with a central issue in both US policy and China's modernization plans: the outlook for science and technology (S&T). The Estimate assesses the S&T environment, the prospects for significant advances in priority areas over the next 15 years, and the effects of S&T achievements and failures on both China and the outside world. In reaching these judgments, the Estimate assumes both political and social stability and general continuity in modernization policies in China based on the conclusions of the recently completed National Intelligence Estimate NIE 13-7-86, *China's Second Revolution*. It also assumes that China will not gain control over the scientific and technical resources in Taiwan. [redacted]

While science and technology are widely used as a single term, they embody two different concepts. Science refers to the pursuit of knowledge through the systematic study of the physical world and its phenomena, while technology refers to the application of such knowledge for practical purposes. Chinese officials have found it increasingly important to emphasize the distinction, because the objectives of science and technology differ, as do their results. Science, with its objective of understanding what happens in nature and why, generally involves long-term, open-ended research. Technology has a more short-term focus on how to achieve specific results, usually involving direct economic benefits. The emphasis in China has clearly shifted to technology. Likewise, this Estimate focuses mainly on technology along with the institutional structure that conducts research and acquires technology for China's industry. [redacted]

KEY JUDGMENTS

Overall, the outlook for the modernization of science and technology in China is favorable:

— Political support for S&T modernization is strong, consistent, and growing.

— Foreign technology is being acquired on an unprecedented scale, and large numbers of Chinese are being educated abroad in science and engineering.

— Research facilities are being better equipped, and management is improving.

— Direct links are being established between research centers and the industrial establishments that are to benefit from the research.

The pace of S&T modernization, however, will be slow for at least a decade because of continuing difficulties in assimilating technologies. For the most part, the labor force is unskilled and poorly motivated, and managers are inefficient. In addition, the infrastructure of technical support, communications, transportation, and energy is inadequate. These problems are compounded by a cumbersome bureaucracy with a penchant to overcontrol society through central planning. This results in low productivity, poor quality control, and slow absorption of new technologies. Cumulatively, they pose a formidable obstacle to improving China's technology levels, upgrading industries, and closing the technology gap with the West.

While these limitations affect the pace at which modern technologies can be absorbed, a more agile and responsive S&T system is nonetheless evolving. Individual scientists and engineers enjoy increasingly attractive opportunities and incentives, better qualified S&T managers are pushing more relevant research, and overall funding for research and development is increasing. The supporting infrastructure is improving the flow of information, S&T journals are flourishing, and research facilities are becoming more independent. Out of this environment we expect S&T to provide important contributions to increased productivity in China, which is the basic objective of modernization.

In addition, S&T modernization will probably accelerate military research and development programs. Important beneficiaries include

China's ground, naval, air, and ballistic missile forces. [1] Foreign technology, in particular, is likely to play a key role in reducing by several years the time it takes to solve critical developmental problems. China already has reached agreements for the purchase of military equipment and technology with 15 countries (see annex D for details).

China may be able to narrow somewhat the gap in selected industrial technologies with the industrialized world over the next decade. The degree of any such narrowing is uncertain, but catching up fully with the West in any of these areas is very unlikely. The general outlook for progress in high-priority areas is summarized below [redacted]

[redacted]

Microelectronics	Gap will widen.
Computers	Gap will widen.
Telecommunications	Gap will remain or widen.
Automated manufacturing	Gap likely to persist.
Transportation	Gap will remain fairly uniform.
Energy	Gap will narrow.
Special structural materials	Gap may narrow.
Biotechnology	Gap will narrow.

Foreign technological assistance is likely to be instrumental in overcoming critical obstacles in both military and civil modernization programs. Demands on S&T from both military and civil users will increase, and China will step up efforts to acquire foreign technology, particularly from the United States. This situation will provide both risks and opportunities.

Of course, China will try to avoid becoming overly dependent for technological assistance on the United States or any other country. To that end, Beijing is establishing a broad network of S&T relationships. Although China currently acts mainly as a consumer of high technology, eventually, Beijing may become a stronger competitor in certain world markets as S&T modernization results in more efficient production.

Sino-Soviet S&T relations are also likely to expand somewhat as China seeks to diversify S&T relationships. At the same time, Soviet-trained scholars in their midfifties may increasingly assume leadership positions within China's scientific community. However, the extent of improved Sino-Soviet S&T relations is likely to be limited because high technology tends to be more accessible in the West. Also, many of China's new S&T leaders are highly critical of Soviet S&T management and they have pressed for reforms along Western lines, despite their

[redacted]

Soviet training. Furthermore, China is moving away from the Soviet S&T model in many respects and may narrow much of the technology gap between them and perhaps even surpass the USSR in some areas, such as certain types of computers. These developments are possible because Beijing enjoys far better access to foreign technology than Moscow does, and because China's leadership has demonstrated a far greater willingness to introduce bold changes.

Large numbers of Chinese students will be studying in the United States as part of the growing US-China S&T relationship. This can be an impetus to better mutual understanding, despite reservations by some party ideologues about the danger of "spiritual pollution" from foreign education and more general concerns about Chinese students who go abroad to study but do not return.

The leadership in Beijing is trying to anticipate the full scope of consequences that S&T modernization is likely to bring. The widespread education of Chinese abroad and the rise of scientists to more influential positions may increasingly influence thinking on political issues. We already see signs of a much more "open" China. While such trends are not likely to undermine the fundamental control exercised by the Communist Party, thinking within the party may increasingly be open to a wider set of influences.

Overall, S&T modernization is contributing to China's economic and military strength, and, as a result, China is becoming more open to selected Western ideas and influence, is developing a larger stake in global stability, and, at the moment, remains disinclined to act in a destabilizing manner. While enhancing China's military capabilities, we do not foresee that S&T modernization will lead to any substantial shifts in China's military balance with the USSR. The balance of forces with other potential adversaries in East Asia is also unlikely to change dramatically over the next 10 years. Despite China's development of new weapons based on foreign technology or purchase of some Western arms, it is unlikely that China can either absorb the technology or field sufficient numbers of more advanced weapons before the late 1990s.

These Key Judgments are Secret

DISCUSSION

The Changing Environment

Perceptions, Goals, and Priorities

1. The strong emphasis on science and technology by the highest political levels in China is likely to continue. This support is based on the view that a dangerous gap exists between China and the major world powers, and that this gap primarily is due to the wide and growing disparity in technology. The leadership also shares a strong desire to reverse the trends that have led to a weak and vulnerable China, dependent on outside sources for an increasing variety of important products.

2. In response to these perceptions of a large and growing gap between China and the world, the "Four Modernizations" began in earnest in 1978 focusing on agriculture, industry, science and technology (S&T) and defense. The goals of this process are loosely defined, usually calling for a quadrupling of economic output between 1982 and the year 2000. According to Chinese statements, as much as half of the gain in productivity over the next few decades is to come from science and technology. The goals, however, are less important than the process of modernization in which the Chinese leaders have demonstrated a willingness to introduce substantial changes to the economic and research systems.

3. Although the modernization process has been remarkably open to ideas from the West, the goal remains a more modern and efficient socialist system, with the Communist Party in full political control. But the party is no longer committed to Maoist notions of egalitarianism that proved particularly stifling to the scientific community in the past. Instead, market forces are being introduced as a means to modernization, but not as the end objective.

4. As part of the modernization process, thousands of technologies have been identified as important in various Chinese modernization studies, plans, and programs. But for the most part, efforts to upgrade domestic S&T capabilities and acquire foreign technologies are focused on eight areas. These areas generally have broad industrial and military applications, such as microelectronics, or address particularly weak links in China's modernization, such as energy and transportation. Currently, the highest priorities are accorded to:

— Microelectronics.

— Computers.

— Telecommunications.

— Automated manufacturing.

— Transportation.

— Energy.

— Special structural materials.[2]

— Biotechnology.

Key Variables

5. China's leadership is increasingly well informed on the requirements for S&T modernization, and, accordingly, their objectives have become more realistic. In particular, their main purpose is to more closely link research and production, thus strengthening industry, agriculture, and the military. China began introducing S&T reforms in the early 1980s to improve the management and organization of research and development. The March 1985 Central Committee decision on S&T reform and several associated measures provide the basic guidance for S&T modernization. The success of these efforts will depend largely on the seven variables discussed in the following paragraphs.

6. ***Political Stability.*** Political instability disrupted two previous attempts at S&T modernization in 1956 and 1962 and poses the greatest threat to the current program. But the prospects for political continuity are good.[3] Political support for S&T is likely to continue to

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[2] Includes advanced composite materials, metals, and ceramics such as high-strength carbon fibers and high-temperature resistant alloys. (U)

[redacted]

Table 1
Estimated S&T Personnel

	1980	1985	1990
Bachelor degrees in natural science	17,000	23,000	28,000
Bachelor degrees in engineering	51,000	113,000	120,000
Total	68,000	136,000 [a]	148,000
Graduate degrees in science and engineering	3,000	8,000	15,000
Chinese students/scholars in United States	4,000 to 5,000	14,000 to 15,000	20,000 to 25,000
Cumulative total Chinese students sent abroad since 1978[b]	10,000 to 13,000	40,000 to 80,000	110,000 to 180,000

[a] By comparison, the United States awarded about 190,000 similar degrees annually and the USSR about 450,000 in the early 1980s.
[b] Data on total Chinese students sent abroad vary widely.

Note: Academic degrees were reinstated in 1981, so 1980 data reflect estimated equivalent four-year studies.

This table is Secret [redacted]

grow for at least the next several years. Nevertheless, the modernization process will be long, and the political leadership will change substantially over the next decade. [redacted]

7. Opposition to China's modernization program has been minimal. Some senior party officials, such as [redacted] object to the pace of reform and some of the details. They argue that opening China to Western influence has had unacceptable side effects, including increased corruption. But overall, the leadership is increasingly united on the need for S&T modernization and the direction that reforms should take. [redacted]

8. ***S&T Personnel.*** Surveys by the State Science and Technology Commission (SSTC) in 1978 concluded that the shortage of skilled personnel was the most serious S&T problem. Recent articles reaffirm that this continues to be a major bottleneck. Ambitious educational goals were established, and Chinese students were sent abroad in unprecedented numbers. The early goals have not been met, but strong efforts to upgrade the quality of science and engineering education continue. Also, widespread study of English and Japanese has been reinstated in China's schools, and foreign textbooks have been introduced. Graduate student enrollment in 1985 was up over 60 percent from 1984, but the results are still meager for a country of over 1 billion people. In 1985 only about 8,000 masters degrees and 58 doctoral degrees were conferred. [redacted]

9. The process of increasing the quantity and quality of S&T personnel in China will be slow (see table 1). A major shortfall is engineers. A study in the early 1980s by the State Planning Commission indicated that China's universities were producing only about 40 percent of the engineers required, whereas they were able to satisfy about 75 percent of the current demand for scientists. This situation is compounded by a shortage of qualified faculty and the rapid increase in enrollment of S&T students. In addition, the cost of upgrading science and engineering at existing universities and opening new universities will be expensive. To help, the World Bank is making loans available for educational development programs. In addition, China is seeking foreign scholars, particularly from the United States, to improve science and engineering instruction in China. [redacted]

10. To alleviate some of these domestic shortcomings, China will continue to send large numbers of students abroad. Educational exchange programs have been established with over 50 countries, although the majority of Chinese students come to the United States. Currently, some 15,000 to 17,000 Chinese students are studying in the US and about 2,700 in Japan. About 70 percent of these students study science and engineering (see inset). While sending students abroad has helped fill important gaps, a shortage of midlevel technicians will continue to

Chinese Students and Scholars Abroad

Policy?	• Encourage both private and government sponsored education and training abroad.
Who goes?	• Initially, faculty and staff from leading universities and research institutes.
For what?	• About 70-percent math, science, engineering. Most at graduate level.
How good are they?	• Perform about as well as US students, in many cases much better. They tend to be serious and hard working.
How many?	• Figures uncertain, but some 15,000 to 17,000 now in the United States, out of 30,000 to 35,000 currently abroad worldwide. • US already has trained over twice as many Chinese as were trained by the USSR, although the US training has tended to be for shorter periods.
Results on return?	• Of those who have returned, many go back to their former organization. Their numbers are becoming significant at leading universities and research centers. Some problems reintegrating, particularly if abroad for over two years. Those who do not go abroad often are jealous; friction results. • Most make significant research contributions. • Many hold seminars; establish information networks. • Most underutilized because of inadequate facilities, although facilities are also being upgraded. • Most have positive attitude toward reforms.

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handicap S&T development. Faced with such problems, more factories are being encouraged to increase vocational training programs at home and abroad. Management training has also become more popular, and several management training centers have been established in cooperation with foreign countries, such as the US-supported management training center at Dalian.

11. Foreign education will continue to be a critical part of improving S&T in China. Despite reservations by some party ideologues about the danger of "spiritual pollution" from foreign education and concerns about students who do not return to China, the leadership will continue to send students and scholars abroad. However, Government-funded scholars now account for about 40 to 50 percent of the Chinese who study abroad, and this share will probably decline as the government tries to shift more of the financial burden of education to local authorities in China, to overseas Chinese relatives, and to foreign universities and foundations. Such efforts to broaden training and education will nevertheless expand China's pool of skilled S&T personnel in the long run. In the meantime, China will continue to experience a shortfall in S&T talent.

12. ***Access to Foreign Technology.*** China cannot close the technology gap alone, so foreign technology will play a critical role in the modernization effort for at least the next decade. A variety of mechanisms will continue to be employed to acquire foreign technology. Business arrangements, including direct purchases, foreign investment, and joint ventures, provide one major avenue for technology transfers. These arrangements often include provisions for training workers and managers in modern production techniques. In addition, technology gained through visiting scientific delegations, students and scholars studying abroad, and foreign publications that are incorporated into S&T data bases will, in the long term, contribute to China's modernization.

13. Access to foreign technology requires favorable policies and practices both on the part of China and Beijing's trading partners. For its part, China has taken several steps to facilitate the acquisition of foreign technology, including new legislation, such as the patent law, to protect foreign investors. Also, special economic zones have been created with preferential tax treatment and land use provisions to attract foreign businesses. The results have been somewhat disappointing thus far in terms of technology transfer to these zones, mainly because investment has been lower than anticipated, and participation has mainly involved assembly of relatively simple products for export. Nevertheless, China continues to seek ways to provide attractive opportunities for foreign investors. For example, recently Beijing promised some foreign firms more access to China's large domestic market in return for technology, but limited access is likely to remain a serious obstacle to improved commercial relations. Moreover, Beijing has begun to penalize

firms that do not offer know-how and technical assistance with their hardware. In May 1985 the State Council formally tied future purchases of advanced equipment to technical cooperation, and Beijing subsequently added midlevel technology sectors such as motor vehicles. [redacted]

14. From the business perspective, much of the initial enthusiasm for trade with China has declined because many firms are not making profits that can be repatriated. In addition, they are finding that the cost of doing business in China is very high, and they are often frustrated in dealing with the Chinese bureaucracy. Consequently, some firms may be less likely to make technology available on attractive terms. But, on balance, China should continue to enjoy good access to foreign technology. Foreign trade agreements are increasing, and new joint ventures continue to be chartered in record numbers. The relaxation of export controls by the United States and COCOM has also improved China's chances for gaining advanced technology through legal channels. [redacted]

15. An additional way to acquire foreign technology involves covert and illegal methods. This approach probably accounts for a small percentage of the total volume, but, it is used both to acquire priority items expeditiously and to gain controlled technologies. [redacted] We believe covert and illegal methods of acquiring technology will very likely continue, despite the generally good access China enjoys using legal means. This is because Beijing fears that important technologies could be denied in the future. [redacted]

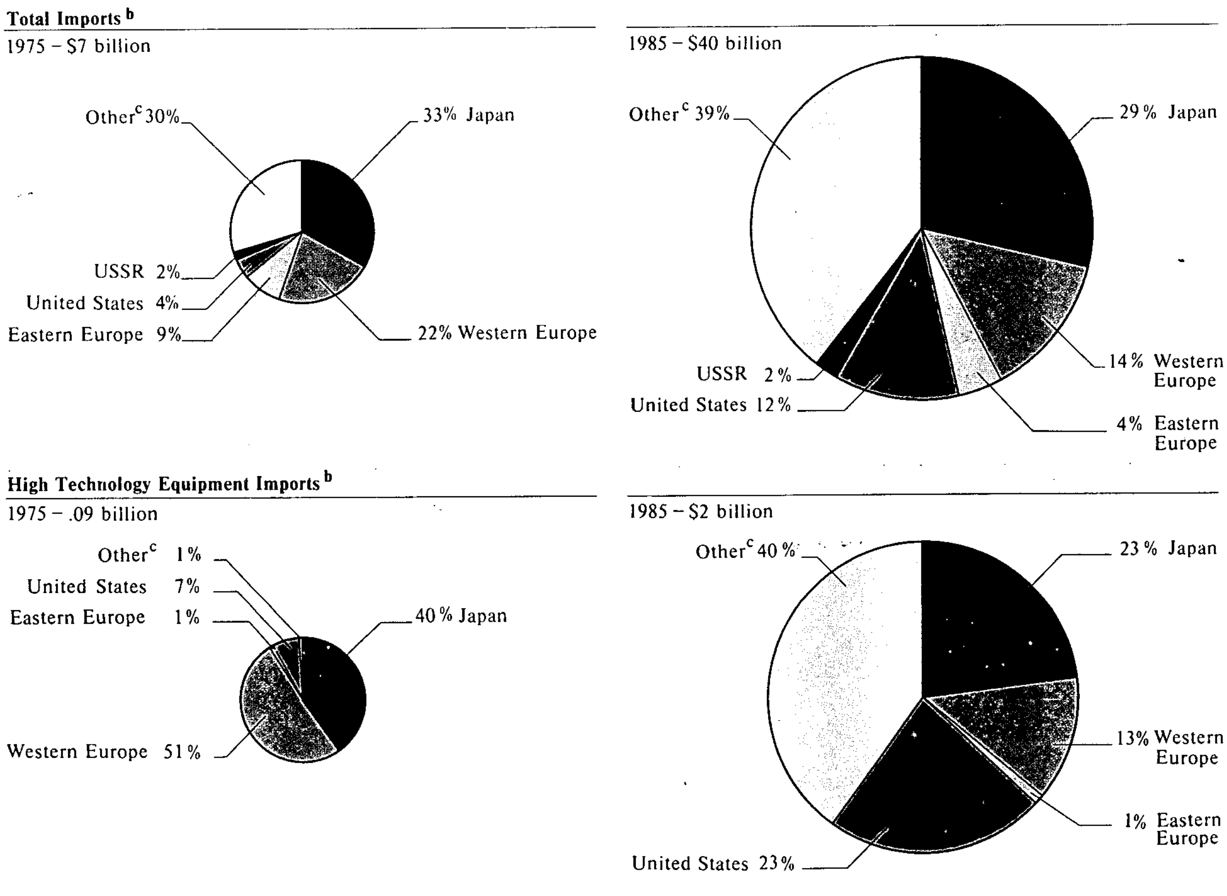
16. Japan and the United States are likely to remain the focus of China's efforts to acquire advanced technology. Japan has established an extensive marketing network in China, aggressively pursued sales, and offered attractive financing packages. But Japan has been rather protective of its know-how. The United States has been more forthcoming with technology and has become an increasingly important source of China's imports, particularly high-technology items (see figure 1). While the United States has gained a larger share of the Chinese market, Beijing is being careful to avoid becoming overly dependent on a single source by diversifying foreign purchases to Western Europe and elsewhere. [redacted]

17. *Management.* A key focus of S&T modernization is to reform research management. The Chinese Academy of Sciences (CAS), universities, and ministries with large R&D components are targets of efforts to motivate scientists and better integrate their research with the production process. In particular, research institutes are being encouraged to seek contracts with industry. Already these contracts account for an average of about 20 percent of the operating budgets of research institutes. As part of this effort, over 100 technology trade fairs were held during 1985 that led to research contracts valued at more than $700 million. Reforms also call for research institutes to become more independent and competitive. CAS may divest itself of some of the nearly 120 institutes that it currently manages, but this is likely to be a contentious issue. In any event, the Academy leadership is supposed to give up day-to-day management of the institutes as more responsibility is shifted to the institute directors. Under the reforms, directors in both military and civil research facilities are to have greater control over their budgets and personnel, including authority to hire and fire staff members. These and other changes in the scientific community represent a clear move away from the Soviet model, which has not served China well over the past 30 years, in the view of the leadership [redacted]

18. These reforms have been in varying stages of discussion and implementation for nearly six years. Thus, to overcome inertia and bureaucratic infighting, a series of "Leading Groups" have been formed with high-level political clout. The S&T Leading Group, headed by Premier Zhao Ziyang, is designed to cut through the many layers of the bureaucracy, which often stifle innovation and change. Another Leading Group, under Li Peng, coordinates the development of the high-priority electronics industry. This coordination includes electronics research, production, and applications. The proliferation of these oversight groups, however, suggests that they too may be having trouble implementing reforms. Key organizations in the S&T community are depicted in figure 2, and annex B describes the organizations and key personalities in more detail. [redacted]

19. Science and technology policy in China is formulated mainly by the State Science and Technology Commission (SSTC) for civil matters and by the National Defense Science, Technology, and Industry Commission (NDSTIC) for military issues. Together, these supraministerial organizations are responsible for managing S&T modernization. They are particularly concerned that the modernization process be smooth

Figure 1
Changing Sources of China's Imports[a]



[a] These charts reflect commodity imports, such as scientific instruments, telecommunications equipment and computers. Other important technology transfers, such as training personnel in manufacturing processes, may be part of joint ventures or other arrangements that are not included in commodity trade data.

[b] Estimates.

[c] "Other" is largely re-exports through Hong Kong of Western products.

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Figure 2
China's Key Science and Technology Actors

Leading Groups

Science and Technology Leading Group	Electronics Industry Invigoration Leading Group
Head	Head
Zhao Ziyang	Li Peng

State Council Commissions

State Science and Technology Commission	National Defense, Science, Technology, and Industry Commission	State Economic Commission	State Planning Commission
Minister in Charge	Minister in Charge	Minister in Charge	Minister in Charge
Song Jian	Ding Henggao	Lu Dong	Song Ping

Academy of Sciences and Key Ministries

Chinese Academy of Sciences	Ministry of Ordnance Industry	Ministry of Electronics Industry	Ministry of Posts and Telecommunications
President	Minister	Minister	Minister
Lu Jiaxi	Zou Jiahua	Li Tieying	Yang Taifang
About 117 research institutes	Subordinate research facilities unknown	3 research academies; about 50 research institutes	About 25 research facilities

Ministry of Aeronautics	Minister of Nuclear Industry	Ministry of Astronautics	Ministry of Machine Building Industries
Minister	Minister	Minister	Minister
Mo Wenxiang	Jiang Xinxiong	Li Xu'e	Vacant
About 25 to 35 research facilities	Number of research facilities unknown	About 25 to 35 research facilities	About 40 research facilities

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because they believe that too rapid modernization could be disruptive. To improve management of this process, a complete census of the S&T community will be taken every three years, with the first census expected to be finished by mid-1986. In addition, SSTC has instituted semiannual surveys of the S&T community to provide feedback on various issues such as job mobility. This survey information provides an independent check on S&T data reported through normal channels. These and similar developments point toward a more efficiently managed S&T system.

20. Leadership of S&T in China is passing from a group of scientists, now in their late sixties and early seventies, who have had substantial training in the West, to a group in their fifties who are primarily Soviet trained. Interestingly, this transition also has coincided with a move *away* from the Soviet model for S&T in China. The new leadership, including Song Jian and his Soviet-trained colleagues, has been critical of Soviet S&T management, and they have pressed for reforms along Western lines. As a result, the emerging science policies are very eclectic, and two broad

research and development strategies are apparent. The traditional, highly centralized strategy still characterizes much research and development in China. This approach focuses the necessary resources to achieve rather narrow, specific objectives. This approach has resulted in notable successes including thermonuclear weapons and the Galaxy supercomputer. At the same time, Beijing intends that a more decentralized structure will evolve and foster S&T advances in microelectronics, computers, and other areas. This strategy emphasizes competition among more independent research facilities.

21. At the individual level, providing incentives to scientists is a major focus of S&T reform, and from the perspective of the Chinese scientist, the plans are encouraging. Living conditions and opportunities for job mobility should improve, albeit slowly. Scientists are now able to obtain patents on their discoveries and do private consulting work for profit. Also, more direct rewards for excellence in research are to be granted. Special incentive award funds are being established, and a National Natural Science Foundation (NNSF) has been formed that will provide scientists with a greater voice in the allocation of research funds. The NNSF, once it becomes fully functional, should also enhance the quality of research through a peer review process rather than relying entirely on administrators to make funding decisions. Promotions may also come quicker, and Beijing is trying to increase opportunities for job mobility. Research facilities are being encouraged to compete for scientists and engineers, but competition and job mobility are not developing as Beijing planned. The job mobility initiative is one of the more controversial aspects of reform because institutes do not want to lose key scientists and the older scientists enjoy the security of the current system that provides lifetime tenure. Other controversial measures include an emphasis on youth. Over 70 of the CAS institute directors have been replaced in the last three to four years by younger, better trained scientists. In some cases, the new directors were selected from outside the institute in a major departure from traditional practices.

22. Another major change in management style is the general opening to the West. For example, several laboratories are to be opened to foreign researchers. Also, foreign scientists frequently serve in important research advisory positions. Similarly, an association with overseas Chinese members of the CAS is being formed to help monitor research abroad. In addition, returning Chinese students are being urged to retain their foreign contacts. These efforts to open the S&T system to outside influence are likely to continue and have largely beneficial consequences for the pace and quality of research in China. Furthermore, the effects are likely to extend beyond the immediate S&T community.

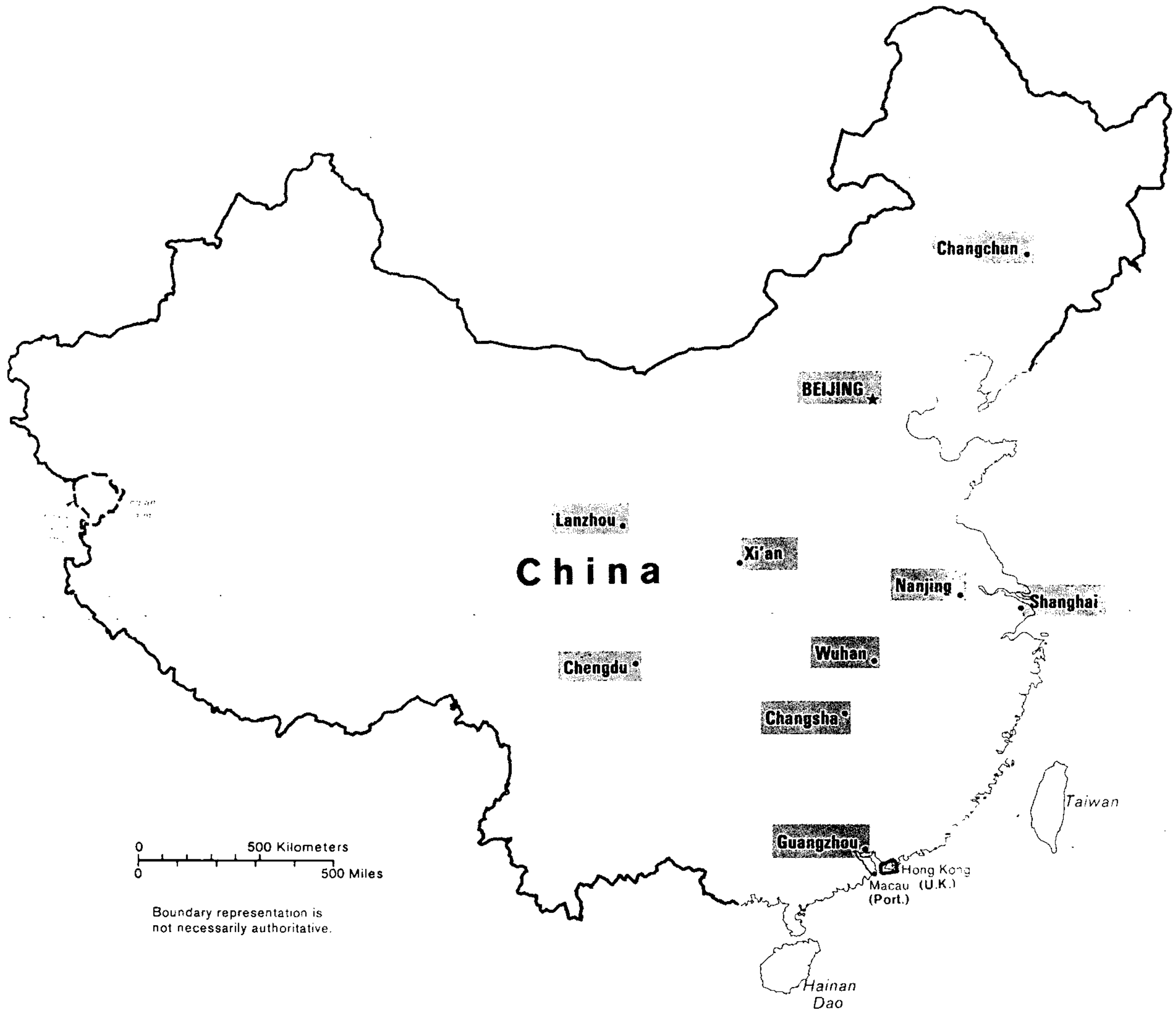
23. ***Infrastructure.*** For the most part, the research environment in China has not been conducive to technological progress. Many research facilities in China were outdated and frequently lacked equipment and related infrastructure to support research and development (R&D). Also, there generally was little sharing of information between research organizations. These conditions often resulted in the duplication of work as well as poor quality research. Such problems and their main causes are well understood in China and are the target of reform and other measures to upgrade the S&T infrastructure. For example:

- Modern research equipment and scientific measurement devices have been accorded high priority for acquisition, both from abroad and from upgraded domestic production facilities.
- An international scientific and technical information system at the Institute for Science and Technology in Beijing has been expanded to include access to several foreign S&T data bases. Plans also call for extending this service to other cities in the next few years.
- S&T publications have proliferated since 1978, and the quality is improving.
- China has joined nearly 100 international S&T organizations to gain better access to information and foreign scientists. This also provides opportunities to train Chinese researchers through participation in multinational research projects.
- High-technology centers are being established around Beijing and Shanghai to concentrate advanced research and production resources.

24. These and other efforts should improve the S&T infrastructure, although results will be uneven. The largest concentration of major research facilities will continue to be in the Beijing and Shanghai areas (see figure 3). Key research facilities will receive priority infusions of personnel and equipment. Despite reforms, old inhibitions against information sharing may be reinforced by the increasingly competitive nature of research in China. Thus, diffusion of information will continue to be slow.

25. ***Funding.*** The cost of modernization is high and funding for S&T will be an important factor in determining the pace of modernization. Government

Figure 3
Top 10 Cities with Leading Research Facilities



	Key Universities	Chinese Academy of Sciences Institutes	Other Major Research Centers	Total
Beijing	15	42	112	169
Changchun	3	5	10	18
Changsha	2	2	6	10
Chengdu	0	6	6	12
Guangzhou	3	7	10	20
Lanzhou	1	6	8	15
Nanjing	7	5	10	22
Shanghai	6	16	47	69
Wuhan	7	10	7	24
Xian	4	3	12	19

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spending for S&T has increased at a slightly greater rate than the expansion of the overall budget. In addition, the central government is encouraging more spending on S&T by local enterprises. At the same time, research institutes will become more independent financially and will offer employees incentives, such as improved housing. But putting research contract reforms into practice will prove difficult because organizations have little experience in treating research and technology as a commodity, and mechanisms to determine their value are not well established. As a result, the cost of research may rise. Also, conflict between central and local interests that characterize bureaucratic politics in China may make implementation of the reforms difficult. Another serious problem will arise when decisionmakers are faced with the issue of how to deal with "unprofitable" research centers. In theory, they should go out of business, but none have been allowed to fail to date.

26. Export trends will also have an important effect on the pace of S&T modernization because China will continue to rely on hard currency holdings to purchase advanced technology. In 1985 our preliminary estimates indicate about an $8.5 billion trade deficit, causing a significant drop in foreign exchange reserves. This has caused Beijing to slow imports, which could affect S&T modernization because China remains highly dependent on imported technology. Nevertheless, technology imports will retain a high priority for funding.

27. ***Assimilation of Science and Technology.*** Regardless of the progress within the S&T community, translating research and technology acquisitions into production continues to be a major weakness. Delays in new projects are common, and, once new facilities come on line, productivity often is well below the expected output—primarily due to low labor productivity and poor project management. Quality control problems, poor maintenance, a lack of spare parts, and similar problems are pervasive. Increases in industrial production also will be closely linked to China's ability to narrow the scope of central planning and gradually allow market forces to determine more economic activity. However, the ability to carry out such decentralization without undermining the party's monopoly of power may prove to be the single most vexing problem the leadership will face. These and other difficulties in absorbing new technology have been attributed to a variety of basic conditions that include:

- *Low labor productivity.* Skilled labor is in short supply. Educational standards are low, and workers are unfamilar with modern technology. Absenteeism is high, and workers are poorly motivated.
- *Poor planning and management.* Managers lack understanding of the market potential for new products. They often lack authority and are not technologically competent.
- *Bureaucratic style.* The locus of authority and responsibility often is unclear, and the bureaucracy tends to overcontrol to the point of stifling initiative.
- *Poor communications and compartmented organizations.* The flow of ideas has been very restricted both on an interpersonal basis and at the societal level. Information sharing between major organizations has been minimal.
- *Inappropriate technologies.* In some cases, technologies have been imported that proved too advanced for China to master.
- *Poor support.* Energy and transportation have been inadequate. Some factories operate only part-time because of electricity shortages. Spare parts and maintenance often are not available.
- *Poor quality control.* Products often are of poor quality. Test and measurement equipment are inadequate, and high standards are not insisted upon by managers.

28. Progress in overcoming the assimilation problem is likely to be slow. In some areas, we expect to see a reduction in the time it takes to apply a new technology to mass production as the quality of the work force and management improves. Progress will be most evident in those industries in which China has long experience with imported plants and equipment, such as petroleum refining and extraction, textiles, aluminum, and chemical fertilizer. Somewhat slower assimilation will characterize developments in the high-technology arena.

29. ***The Sum of the Variables.*** Trends in the key S&T variables are generally favorable, although progress is likely to be slower than desired. Even though improving at a relatively slow pace, the emerging S&T system probably will gradually become more responsive to a wider range of end user demands, primarily because of more decentralization and less isolation of the research community. The system also will eventually be more agile as information begins to spread more rapidly and research centers are able to react more quickly to promising new developments, espe-

cially with the infusion of computers, modern scientific equipment, and foreign-educated students. Nevertheless, China is likely to become increasingly dependent on foreign technical assistance to sustain positive trends through the end of the century.

30. Inevitably, some setbacks will occur in S&T modernization. In some cases, imported technology will be inappropriate for China's labor force or energy resources, in others, raised public expectations about modernization will be dashed. But such problems have already been anticipated. Articles have appeared cautioning people not to expect a smooth transition to high technology. In one example, a "bathtub curve" is described in which high failure rates are to be expected both during the early stages of a process, when new technologies are introduced, and during later stages, as equipment wears out and the technology becomes obsolescent. In between, though, should lie a sustained period in which failure rates are low. The intended message is: "Don't change policy prematurely because of early failures."

31. Over the next several years, selected indicators will suggest whether the pace of S&T modernization is likely to be sustained (see inset).

Positive Indicators	Negative Indicators
• Greater leadership role for younger, better educated scientists and technicians.	• Greater role of party in S&T affairs.
• Continued emphasis on education and training for all people.	• Resurgence of ill treatment of intellectuals.
• Increased openness to foreign technology, including management techniques.	• A swing back to more centralized planning.
• Continued top-level public endorsement of S&T reforms.	• Increased charges of corruption.
• Sustained economic growth.	• Decline in foreign exchange reserves.
• Return to China of a high percentage of students sent abroad.	• Restrictions on students abroad and drop in number sent abroad.
• Freer flow of foreign and Chinese S&T personnel within China.	• Continued resistance to the mobility of S&T personnel.
• Improvements in economic productivity attributable to technological innovation.	• Reduced foreign investment.

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[redacted]

Prospects for S&T Achievements

Scientific Frontiers

32. China's emphasis on applied research and development work threatens to hinder advancements in science. The leadership is aware of this and is increasing funds for basic research. But basic research in China includes that which may be quickly applied to national needs. Thus, in general, fewer resources will be available for theoretical work, and experimental research—which already accounts for a very low share of scientific work—probably will fall even further behind Western standards. Thus the results are more likely to be evolutionary advances, rather than revolutionary breakthroughs. Nevertheless, the scale of research in China, involving about 9,000 facilities, probably will produce some significant scientific results. However, we cannot predict in which fields these are most likely to occur. [redacted]

33. Although the quality of science in China has in general not been on a par with the West, a few Chinese scholars have gained international prominence. Particularly strong research fields in China include magnetic materials, mathematics, high explosives, medicine, plant genetics, and virology. Similarly, the top research institutes in China are doing work in a few high-priority areas that compares favorably with that of research facilities in the West. Several of China's top research centers are noted in the inset below and undoubtedly there are more. [redacted]

Leading Centers of Research in China

Centers	Areas of Excellence
Fudan University.	Lasers, optics, electronics.
Qinghua University.	Microelectronics.
Shanghai Jiaotong University.	Computers, telecommunications.
Hefei Institute of Plasma Physics.	Physics.
Beijing Institute of Physics.	Molecular beam research.
Xian Institute of Optics and Precision Mechanics.	Lasers, high-speed photography.
Software Technology Institute.	Computer software.
Shanghai Institute of Biochemistry.	Biotechnology.
Beijing Institute of Genetics.	Plant genetics.
National Defense S&T University.	Supercomputers, software.
Shanghai Institute of Metallurgy.	Semiconductors.
Shanghai Institute of Ceramics	Silicon crystal growth

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Technological Advances

34. Although China is at a very early stage of development and is faced with substantial obstacles, concerted efforts to focus the best talent and sufficient resources, along with the introduction of foreign technology, should increase the levels of technology available in China in several areas (see annex A). China's efforts to close the technology gap with the West, however, are hampered by such factors as the low level of indigenous R&D and continued technological advances in the West. Among the priority technologies, we expect China to narrow the gap in shipbuilding and air transport, energy, special structural materials, and biotechnology. We believe the gap will widen, however, in microelectronics, computers, telecommunications, automated manufacturing, and road transport. The general outlook for progress in high-priority areas is summarized in the inset and discussed in more detail in annex A.

China's Technology Gap

Microelectronics	Nine to 12 years behind now. Making progress but much slower than the West. Gap will widen.
Computers	
Microcomputers	Approximately five years behind now, using imported components. Gap will widen.
Minis & Mainframes	More than 10 years behind. Gap will widen.
Supercomputers	Five to 10 years behind, using imported components. Gap will widen.
Telecommunications	
Switching	Domestic systems 20 to 25 years behind, imported systems three to five years behind. Gap will remain.
Fiber Optics	Research three to five years behind, production five to seven years behind. Imported technology will allow progress but slower than West. Gap will remain or widen.
Satellites	Five to 15 years behind on communications satellites, using some imported components. Gap will narrow as China progresses in C & Ku band, then widen as West moves to higher frequencies.
Automated Manufacturing	Gap likely to persist.
Transportation	
Rail	More than 10 years behind. Gap will remain fairly uniform.
Shipping	Gap narrow and getting narrower.
Road	More than 10 years behind. Gap will widen.
Air	Five to 10 years behind. Gap will remain fairly uniform or narrow slightly.
Energy	
Coal mining	Five to 10 years behind. Gap will narrow.
Petroleum exploration and production	More than 10 years behind. Gap will narrow.
Hydroelectric	Five to 10 years behind. Gap will narrow.
Nuclear	10 to 15 years behind. Gap will probably narrow slightly.
Special Structural Materials	Five to 10 years behind. Gap may narrow.
Biotechnology	Three to 5 years behind. Gap will narrow.

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35. The extent to which the technology gap will be narrowed also is related to the success of economic reforms. While we view the prospects for the economic reforms as positive, on balance, it is also plausible—though less likely—that the reforms will unravel. Such an outcome would likely lead to setbacks across the board in economic, scientific, and technical cooperation with the West and may also contribute to a widening of the technological gap with the West. [redacted]

36. Progress relative to the Soviet Union should be notable, particularly in computers and biotechnology. This is because China enjoys better access to foreign technology than the Soviet Union and stands to benefit considerably from sending large numbers of students abroad. China also has undertaken more sweeping reforms than Moscow in the organization and management of science and technology. Relative to other developing countries, China will also make substantial gains. Yet, on balance, China will be a net importer of high technology from the West. [redacted]

Consequences of S&T Modernization

37. The main consequences of S&T modernization efforts will be in the technological transformation of industrial enterprises in China. Traditional industries will increasingly benefit from a wide variety of new technologies. For example, microelectronic sensors in boilers will facilitate more efficient use of energy resources, while computers will assist scheduling, testing, and inventory control. The net result will be increasing productivity in some areas, which is the primary objective of S&T modernization. [redacted]

38. In addition to gaining from increased industrial productivity, the military sector will also both drive and benefit from the acquisition of foreign technology and the enhancement of domestic research capabilities. Military R&D programs already in progress are likely to be accelerated (see inset).[4] Foreign technological assistance probably will reduce by several years the time it takes to solve critical problems, such as have been encountered in jet engine manufacturing. Thus, access to foreign technology probably will be the most important single factor in the modernization of China's military inventory. [redacted]

[redacted]

Military and Space Programs That Could Benefit From S&T Modernization [a]

Space
- New heavy-lift launch vehicle.
- New navigation and geodetic satellites.
- New meteorological satellite.
- New warning and ocean surveillance satellites.
- Improved photo and ELINT reconnaissance satellites, communications satellites.

Ballistic Missile Forces
- New solid-propellant ICBM.
- New multiple reentry vehicle capability.
- Improved warheads, guidance systems.

General Purpose Forces
- New main battle tank.
- New armored personnel carrier/infantry fighting vehicle.
- New antitank guided missile.
- New low altitude surface-to-air missile.
- New truck.
- Improved munitions.
- Improved logistics system.

Naval Forces
- New class frigate/destroyer.
- New cruise missile.
- New shipboard surface-to-air missile.
- Improved antisubmarine warfare, electronic warfare, and shipboard command and control systems.

Air Forces
- New fighter-bomber.
- New air-to-air missile.
- Improved radar, fire control, armaments, engines, and fuselages.

[redacted]

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39. While the developmental process will be speeded up in many areas, the production of new weapons and equipment by China is not likely to substantially alter the Sino-Soviet military balance. Soviet ground, naval, and air forces in the Far East already possess weapons more sophisticated than those currently being fielded by China, and Moscow's continuing modernization of its forces in the Far East make it highly

unlikely that Beijing will erode Soviet military superiority. The balance of forces with other potential adversaries in East Asia is also unlikely to change dramatically over the next 10 years. Despite China's development of new weapons based on foreign technology or purchase of some Western arms, it is unlikely that China can either absorb the technology or field sufficient numbers of more advanced weapons before the late 1990s. [redacted]

40. Although the pace of modernization will be slow, successful use of technology will create additional demands for research and development. Increasing demands on S&T will lead Beijing to intensify efforts to acquire foreign technology, while attempting to avoid becoming overly dependent on any particular foreign source. China has generally found technology more accessible in the United States than anywhere else. Thus, S&T ties to the United States will gain a momentum that will be difficult for Beijing to change. [redacted]

41. In addition to pressing for better access to technology, Beijing will seek help to encourage Chinese students to return home. The leadership has expressed increasing concern about the percentage of the over 40,000 students who have gone abroad for study since 1978 and have not returned to China. Some have remained in the West, particularly in the United States, and accepted high-paying, technical jobs. While a few may be engaged in some form of industrial espionage, most have simply been attracted by US prosperity and freedom. These trends have caused Chinese officials to become seriously concerned about a "brain drain" that they can ill afford. [redacted]

42. For the USSR, S&T modernization in China poses some risks and opportunities. Not only is Beijing clearly moving away from the Soviet model, it is establishing some S&T relations with Eastern Europe that may trouble Moscow. Should Beijing's reform efforts be even relatively successful, the Soviet model would be further discredited in the eyes of the Third World. On the other hand, Moscow can use China's desire for technology to improve relations through S&T exchanges. Some Chinese students may even go to study in the USSR where Beijing can be assured that few are likely to remain. In addition, some Chinese enterprises are anxious to expand trade relations with the USSR because it is much easier to compete in the Soviet market. Their products sell for three to four times the value that they can command in the Western market. In addition, they can save hard currency by countertrade arrangements. But improvements in Sino-Soviet S&T relations are likely to be limited because the West provides a much better source of advanced technology. [redacted]

43. For the rest of the world, China's S&T modernization—to the extent that it contributes to significant industrial advances—suggests that Beijing may play a larger role in the world market, both as a consumer and as a competitor. China's ability to export both raw materials and products involving low to medium levels of technology, such as machine tools, will be strengthened by technological improvements. As Chinese goods improve in quality, they will become increasingly competitive on the world market. [redacted]

44. Beyond these economic and military possibilities, S&T modernization may also have unintended social and political consequences in China. S&T is at the leading edge of reform and has contributed in large measure to the increased openness noted in China. Scientists and engineers in particular have been granted exceptional opportunities for travel and study abroad. This broad exposure encourages freedom of thought and could increase pressure for social and political changes in China. It also may raise expectations that similar opportunities and freedoms should be made available to other groups. While such developments are not likely to undermine the fundamental control exercised by the Communist Party, such openness will contribute to the broader problems Beijing's leaders will face: how to open China—for economic and technological reasons—without seriously undercutting the party's monopoly of power. [redacted]

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Science and Technology in China's Modernization

National Intelligence Estimate
Volume II: Annexes

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NIE 13-7/2-86/II
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The following intelligence organizations participated in the preparation of the Estimate:

The Central Intelligence Agency, the Defense Intelligence Agency, the National Security Agency, and the intelligence organizations of the Departments of State, the Treasury, and Energy.

Also Participating:

The Assistant Chief of Staff for Intelligence, Department of the Army

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NIE 13-7/2-86/II

SCIENCE AND TECHNOLOGY IN CHINA'S MODERNIZATION

VOLUME II: ANNEXES

Information available as of 25 June 1986 was used in the preparation of this Estimate, which was approved by the National Foreign Intelligence Board on that date.

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CONTENTS

PREFACE

This Estimate is published in two volumes. Volume I is the Key Judgments and Discussion. Volume II contains the supporting annexes. (U)

ANNEX A

Priority Technologies

Microelectronics

1. Microelectronics is a top priority in China's S&T modernization because it is the basis for producing computers, telecommunications equipment, and other electronic products that are vital to China's industrial and military modernization. China's investment in microelectronics production technologies in the last five years has been significant. However, China's microelectronics industry will be built almost entirely on foreign technology. Because of this dependency, the pace of development in China's microelectronics industry will be determined in large part by the ability to acquire and assimilate the necessary fabrication equipment. [redacted]

2. Currently the microelectronics industry in China can produce some 16k DRAM (dynamic random access memory) devices. This capability reflects production lines capable of processing integrated circuit (IC) designs down to the 5 micron level. China's current production is based largely on two- and three-inch wafers, although the yields are relatively low. Within the next few years China may begin producing some 64k DRAM and 16k SRAM (static random access memory) devices. By the mid-1990s, a few of the better semiconductor production facilities may process four-inch wafers and be capable of producing ICs with design rules at the 2 to 3 micron level. [redacted]

3. Microelectronics production equipment is expensive and difficult to install and operate, so progress is likely to be slow. Even after the new equipment is delivered, several years often are required before a microelectronics facility in China reaches full production potential. Shortages of skilled personnel, reliable power sources, and inadequate quality control are among the major impediments to progress. Additionally, current domestic production focuses on simple circuits for consumer products, to the detriment of developing capabilities to produce more advanced ICs. Moreover, factories will be reluctant to fund purchases of new equipment frequently enough to adopt the newest technologies. [redacted]

4. The Leading Group for the Invigoration of the Electronics Industry is working to establish several major centers for the development of semiconductors and computers, but progress has been slow—in part due to funding problems and bureaucratic rivalry among the cities wishing to host the centers. In the meantime, several CAS facilities including the Institute of Electronics, the Institute for Semiconductors, the Institute of Electrical Engineering, and the Ministry of Electronics Industry (MEI) carry out electronics research. The MEI, with 2,400 enterprises, also manages the development and production of electronics products for both civilian and military needs. However, most of the new microelectronics technology introduced in China within the next 10 years probably will come from foreign sources. [redacted]

Computers and Software

5. By the 1990s China's modernization programs will begin to realize important benefits from the strong emphasis on developing computer capabilities. Deng Xiaoping, Premier Zhao Ziyang, Party Chairman Hu Yaobang, and other senior officals have specifically endorsed the production and use of computers in China. Also, Chinese access to technical literature has played a key role in developing computers in China. Even at this early stage, progress has been impressive. In 1983 the Chinese unveiled the Galaxy supercomputer, which—though it reflects mid-1970s technology and may operate at only 25 percent of capacity—is an achievement that continues to elude the Soviet Union. [redacted]

6. Much of China's success is due to access to foreign technology. China has been able to buy a wide variety of Western computers, and over a hundred foreign firms have been involved in negotiations to set up computer production lines in China. These lines contributed in particular to China's production of microcomputers, which are three to five years behind the West. Also, access to technical literature has played a key role in developing computers in China. For example, knowledge of parallel architecture from such publications probably was critical in producing the Galaxy. In addition, large numbers of Chinese

[redacted]

students have enjoyed access to the best schools and research facilities in the West. We estimate that roughly two-thirds of China's computer inventory is imported. Most of the domestically produced computers—more than 30,000 last year—rely heavily on imported parts. China's growing computer industry already numbers over 90,000 employees in several dozen research facilities, 111 manufacturing plants, and 40 service organizations. [redacted]

7. However, the industry has been characterized by little attention to standardization, long delays in establishing production lines, and relatively low levels of productivity once they are operational. For example, a microcomputer production line imported from France in 1979 did not go into production until 1983. By the time computer lines become operational, they often are obsolete. China has yet to make the transition in mass production from 8-bit to 16-bit microcomputers. Chinese computers also tend to be more expensive and less reliable than similar models available in the West. In addition to problems in domestic production, computer imports were drastically curtailed in 1985 after several years of sharply rising purchases, in part to protect the emerging domestic industry and to conserve hard currency reserves. [redacted]

8. The use of computers also is growing rather slowly. About 70,000 computers are sitting in warehouses, and as many as 80 percent of the approximately 200,000 computers in China are not being used effectively. The lack of trained personnel, software, peripheral equipment, and supplies contribute to this poor utilization of computers. [redacted]

9. Chinese software may develop somewhat faster than hardware because it involves primarily mental labor rather than the sophisticated equipment necessary for hardware production. One major software application is Chinese character representation and translation. Two major centers for software development are being established, each with about 1,000 programers, as part of a Chinese objective to increase the number of software specialists from about 10,000 now to about 100,000 by 1990. [redacted]

10. While Chinese computers probably will not be a major factor on the world market in the next decade, China may narrow significantly the gap with the Soviet Union in computer technologies in the 1990s, if present trends continue (see table A-1). These trends include encouragement of the proliferation of computers by the top political leadership, access to foreign technology, and thousands of students studying computer science abroad. [redacted]

Table A-1
Computers in China and the USSR, 1985 [a]

Number of units (except where noted)

	China	USSR
Stocks	**200,000**	**66,000**
Microcomputers	190,000	6,000
Minicomputers/mainframes	10,000	60,000
Domestic output	**32,000**	**5,000 to 7,500**
Microcomputers	30,000	1,000
Minicomputers/mainframes	2,000	4,000 to 6,500
Imports		
Units	65,000	4,000 to 5,000
Value *(million US $)*	328	NA

[redacted]

11. China's relatively slow progress in the production and use of computers should not lead to complacency on our part, however. Substantial resources and talented people are, no doubt, working on projects that we are not aware of and could achieve major breakthroughs. The Galaxy supercomputer is an example of the type of a successful project the Chinese were able to keep secret, despite the involvement of over 20 facilities working over a five-year period and the use of many foreign components, probably including about 200,000 integrated circuits from the United States. [redacted]

12. Research on computers and software is conducted at over 100 facilities operated by the CAS, universities, factories, and R&D facilities of the Bureau of Computer Industry (BCI) of the Ministry of Electronics Industry. Among the leading R&D facilities are the Institute of Computer Technology, the National Defense S&T University at Changsha that worked on the Galaxy supercomputer, and the Beijing Research Institute of Electronic Applications. Despite the expansion in computer and software R&D facilities, China will continue to depend heavily on foreign technology for major advances over the next decade. [redacted]

Telecommunications

13. Telecommunications research is conducted primarily by the Ministry of Posts and Telecommunications (MPT), the MEI, and CAS. Among the important subordinate research facilities are the Fourth Radio

Research Institute in Xian, the Beijing Communications Research Institute, the Shanghai Microwave Research Institute, Xian Electromechanical Laboratory, and the Communications, Telemetry, and Telecontrol Research Institute in Hebei. Satellite R&D is conducted largely by the Chinese Academy of Space Technology, subordinate to the Ministry of Astronautics Industry. The military is a driving force behind both fiber optics and communications satellite programs.

14. Modernization efforts in this high-priority area are focused on acquiring the manufacturing technologies needed for production of modern communications systems, including high-capacity digital transmission and switching equipment, satellite components, fiber optics, and military command and control systems. Domestic production capabilities have lagged well behind rapidly increasing demands. China produces mostly analog equipment, for example, but plans to convert to digital systems for high-speed data transmission and secure telecommunications. China's indigenous research and development in telecommunications are hampered by poor quality and limited availability of components, inadequate technical knowledge, lack of test equipment, and manual production lines. In the past several years, China has purchased advanced systems and some production technology that will considerably improve telecommunications services offered, although it will continue to be dependent on foreign technology.

15. Domestic production capabilities for telephone switching gear are largely limited to electromechanical systems based on 1960s technology and some electronic controls. The Chinese press announced the first domestically produced microprocessor-controlled switch in mid-1985, but no further information on this claim is available. A Chinese joint venture with a Belgian subsidiary of a US firm began operations in late 1985, and has the potential for significantly enhancing Chinese switching capabilities.

16. China has made progress in developing communications satellites, but some problems have emerged. China has launched two communications satellites, a significant accomplishment, but they have limited capabilities and are experiencing operational difficulties. We believe the satellites include some foreign components despite Chinese claims of being domestically produced. China also has given conflicting signals on procurement of foreign satellites. Beijing recently indicated that plans to purchase foreign satellites, including a direct broadcast satellite, have been canceled. But we believe that the many problems facing Chinese communications satellites will eventually lead Beijing to reenter the international market and possibly purchase or lease transponders, or buy an entire satellite, perhaps even one already in orbit.

17. Progress also has been slow in developing a direct broadcast communications system. Negotiations on the purchase of direct broadcast satellites have been drawn out over several years, in part because of an inability to decide which type of system should be used (Ku, C, or S band), differing views on the preferred source, or the need for foreign procurement. (S NF)

18. The Chinese have made progress in their research on fiber optics, although they are experiencing problems in key areas such as single-mode optical fibers, transmission devices, and large-scale production. China has several dozen short fiber optic lines in operation. According to Chinese press reports, most are 8.5 megabits per second, although they do claim some are 34 megabits per second systems. China has signed agreements with several foreign suppliers for the purchase of high-speed 140 megabits per second fiber optic transmission systems for both intercity and intracity use. The sale to China of technology for fiber optics and fiber optic transmission systems requires COCOM approval, which slows the acquisition process. Nevertheless, China has purchased, with COCOM approval, the technology, equipment, and training to produce fiber optic cable and some components. By the late 1990s, fiber optic systems probably will link Beijing, Shanghai, Shenyang, Nanjing, Wuhan, Guangzhou, and a few other major cities.

Automated Manufacturing

19. China is in the very early stages of developing automated manufacturing capabilities. In 1985 there were only about 100 robots in China, located mostly in research facilities, such as the Shenyang Institute of Automation (SIA), Qinghua University, Chengdu University of Science and Technology, and Jiaotong University. The Ministry of Machine Building Industry also conducts robotics R&D. A national center for robotics is to be established at SIA by 1989, but to date most of the robots have been imported and the 10 or so that have been assembled in China involve largely foreign components. They represent first-generation robotics for the most part, capable of point-to-point transfer operations. Work is just beginning on second-generation robotics that involve continuous computer control of spatial motion for light assembly and processing. Some computer-numerical-controlled machines are being produced, while considerable Western computer-aided design, manufacturing, and

testing (CAD, CAM, CAT, respectively), technology is being imported. Joint ventures in these areas are being sought and some research on robotics is beginning.

20. The gap in automated manufacturing capabilities between China and the West is likely to persist. China will have to master microelectronics and computer technologies before substantial advances in robotics are likely. Despite the many Chinese students abroad studying key subfields, such as software development and programming, assimilation of new technologies probably will be slow.

Transportation

21. Indigenous research on transportation systems is weak. Much of it is conducted by research components of factories under the various ministries. The resulting Chinese designs for vehicles, aircraft, and ships draw heavily on foreign models. This situation is unlikely to change in the foreseeable future. Thus the vast majority of technological improvements in the transportation sector over the next decade will be the result of technology transferred from abroad. In particular, joint ventures and licensing arrangements will be critical to upgrading both the methods of production and the vehicles produced.

Energy

22. Energy research and development is conducted by facilities under the CAS, the Ministry of Coal Industry, the Ministry of Petroleum Industry, the Ministry of Water Resources and Electric Power, the Ministry of Nuclear Industry, the Ministry of Machine Building Industries, plus several universities. The Institute of Atomic Energy in Beijing, the Institute of Energy Resources, and the Shanghai Institute of Nuclear Research are among the key CAS energy research organizations. This broad research base, combined with active programs to acquire foreign technology, should improve the overall energy picture in China. Nevertheless, the demand for energy is outstripping China's ability to increase production.

23. China's severe shortage of electric power will continue to limit the pace of economic expansion and modernization for at least another decade. Existing shortages that result in many factories operating well below capacity are compounded by the rapidly increasing demand for power that exceeds China's ability to expand power production. Efforts to reduce this gap involve a wide variety of technologies necessary to more efficiently convert China's abundant natural resources into a reliable, widespread supply of energy.

Table A-2
China: Energy Production

Million tons of coal equivalent [a]

	1980	1985	1990 [b]
Total	**637**	**840**	**998**
Coal	442	606	714
Oil	152	179 [c]	214
Hydroelectric	24	38	50
Gas	19	17	20
Nuclear	0	0	NEGL

[a] According to official Chinese conversion factors, 1 metric ton of coal equivalent energy is defined as the amount of fuel required to provide 7 million kilocalories of heat energy. This is equivalent to 1.4 metric tons of raw coal, 0.7 metric ton of crude oil, 752 cubic meters of natural gas, and 2,421 kilowatt-hours of electricity.
[b] Estimated.
[c] About 20 percent of the oil production was exported.

This table is Unclassified.

Most of these technologies are readily available from abroad, but the Chinese preference to produce equipment, rather than buy end items, has delayed modernization of the energy sector.

24. Coal will continue to account for over 70 percent of China's primary energy (see table A-2). Production increased to 850 million metric tons of raw coal in 1985, surpassing the coal output of the Soviet Union. About half of the production is from the more modern large-scale mines, which are only about one-third mechanized. The other half is provided by small mines that usually lack modern equipment. To meet increasing demands, the coal-mining process will need to be increasingly mechanized. But, progress has been slow in establishing manufacturing lines to produce modern mining equipment. In addition to the shortage of mining equipment, transportation is a serious obstacle. China's railroads cannot currently move the coal as fast as it can be mined.

25. Oil exports are essential to modernization because they provide more than 20 percent of China's foreign exchange. But offshore exploration has been disappointing, and onshore exploration has only recently increased. However, foreign technology has improved both production and exploration. More surveying technology is being incorporated, along with computers to process the large volume of seismic data collected. As exploration shifts to more difficult locations, advanced technology will be increasingly in demand. To help attract this technology, China is now

willing to allow foreign involvement in onshore exploration. China is also upgrading drill bit manufacturing and other important technologies. At the same time, Chinese crews are becoming more proficient at using modern drilling methods. To keep pace with expected improvements in drilling, China's refining capacity is to increase by 30 percent over the next five years, according to plans. Much of this expansion will incorporate foreign technology. However, the declining price of oil may cause Beijing to scale back some of these plans. In a related development, China plans to convert oil-burning electrical power plants to coal. This will allow additional heavy fuel oil to be further refined to more valuable, lighter products, such as gasoline. [redacted]

26. Hydroelectric power has tremendous potential in China, although the main sources are located in the southwest, a great distance from power-short areas. One major emphasis in hydroelectric power has been on establishing a large number of smaller generating plants to supply primarily rural users. Overall, hydroelectric power output has grown at over 10 percent over the last five years. Further increases in hydroelectric power probably will involve substantial imports of foreign technology, including generators and automated production lines for large generators. [redacted]

27. Plans to develop nuclear power to supplement existing energy sources have been delayed. Although China is attracted by several features of nuclear power including the ability to locate plants near the industries requiring the power, the high cost of developing nuclear power has limited the scale and progress of development. Completion of China's first nuclear power plant has been postponed several times and now is delayed to 1990. This 300-megawatt (MW) reactor will rely heavily on foreign parts and technology. Plans also call for about six more reactors in the 600- to 1,200-MW range to begin construction in the next few years, but two of these are likely to be shelved indefinitely. Even if all these plants come on line, they will contribute less than 5 percent of China's power by the end of the century. China's plans to produce small, 150- to 300-MW reactors for sale to Third World countries are also unlikely to materialize in the next five to 10 years. [redacted]

Special Structural Materials

28. Research on special structural materials is conducted under the auspices of the CAS, several ministries, including the Ministry of Aeronautics Industry, and universities. Among the more important CAS research facilities in this field are the Beijing Institute of Chemistry, the Shanghai Institute of Metallurgy, the Beijing Institute of Chemical Metallurgy, the Shanghai Silicate Institute, and the Shenyang Institute of Metals. Chinese research in metallurgy, ceramics, and composite materials appears to be quite good based on published research and papers presented at international conferences. Translating the research into production, however, remains a major problem. [redacted]

29. Military applications of advanced composite materials—including reentry vehicles and rocket motor casings for ballistic missiles—have been an important motivation behind China's intensive efforts to establish capabilities to produce carbon-carbon and other advanced materials. Considerable progress along these lines has been achieved in laboratory research, but the manufacturing technology for volume production has not yet been mastered. [redacted]

30. Several of China's efforts to acquire advanced materials technology have paid off. For example, Kevlar-type high-tensile-strength aramid fibers were produced in a CAS laboratory in 1979, and limited production was undertaken in 1982. Also, the most significant progress has been made in carbon-carbon materials [redacted]. But, in most cases, these materials are produced in small quantities, and quality control is not consistent. Therefore, foreign fibers and production lines will continue to be sought after. [redacted]

31. Interest in metal matrix composite materials has been high, possibly for high-temperature applications such as jet engine turbine blades. Although several complex titanium and nickel-based alloys suitable for high-temperature applications have been developed in China, production problems still are prevalent. As a result, China's interest in acquiring casting and automated production lines remains high. [redacted]

32. For the most part, ceramics research in China probably lags the West by five to 10 years, particularly when it comes to production technologies. Much of the progress achieved over the last five years has involved Chinese scholars studying abroad and Chinese scientists during visits to foreign research facilities. Nevertheless, important new developments will be increasingly possible from scientists working at research facilities within China that are being upgraded. [redacted]

[redacted]

[redacted]

Biotechnology

33. In biotechnology, basic research tends to be more advanced than applied research. Advanced research has been noted in microbiology, protein synthesis, and genetic engineering to produce interferon and other advanced pharmaceuticals. Production technology, however, significantly lags research capabilities. Problems that result from the gap between research and production facilities are exemplified by the recent development by the Shanghai Institute of Biochemistry of a genetically engineered vaccine for a strain of hepatitis prevalent in East Asia. Even with this research breakthrough from China's premier biotechnology research institute, there is a lack of technology and marketing expertise needed to produce the vaccines in sufficiently high volume and quality for the marketplace. China, realizing that this gap exists, is taking measures to close it by entering into joint ventures with foreign firms. [redacted]

34. Agricultural applications of biotechnology are a high priority of the Chinese Government. The Chinese agricultural science community, composed of the CAS and the Chinese Academy of Agricultural Sciences, (CAAS) have a strong base in traditional agricultural research, which is exploited for biotechnology applications. The major factor preventing rapid progress is the gap between basic and applied research and the production and field support infrastructure to exploit the capability. CAAS attempted, with moderate success, to obtain foreign technology to correct their problems via joint ventures and targeted collaboration projects with foreign government and corporations. But agricultural production technology, such as planters, harvesters, and other machinery, remains primitive. Similarly, pesticides and other agricultural chemicals have tended to be neglected in Chinese research. [redacted]

[redacted]

ANNEX C

China's International Science And Technology Agreements, 1978-86 (June)

Algeria

Jan 1982	S&T cooperation

Antigua and Barbuda

Jun 1984	Technology agreement

Argentina

Jun 1980	Economic, S&T cooperation
Aug 1983	Program on S&T cooperation 1983-84
Oct 1983	Scientific and technological cooperation
Apr 1985	Agreement on peaceful use of nuclear energy

Australia

Jun 1979	S&T cooperation
May 1980	S&T cooperation agreement
Oct 1981	Technical cooperation program
Apr 1982	Memorandum of understanding between State Science and Technology Commission (SSTC) and Academy of Technological Sciences of Australia
Apr 1983	Memorandum of geological S&T cooperation
Apr 1985	Agreement on scientific cooperation
Nov 1985	S&T cooperation—five years

Austria

Nov 1980	Long-term agreement on economic industrial and technical cooperation
Apr 1984	S&T cooperation

Bangladesh

Mar 1978	S&T cooperation
Mar 1979	S&T cooperation
Feb 1980	Protocol on economic and technical cooperation
Jun 1980	Protocol on S&T cooperation
Nov 1982	Protocol on S&T cooperation
Mar 1986	Economic and technical cooperation

Belgium

Jun 1979	Economic, industrial, S&T cooperation
Nov 1979	Economic, industrial, S&T cooperation
Dec 1980	S&T agreement

Botswana

Apr 1978	Economic and technical cooperation

Brazil

Mar 1982	S&T cooperation
Aug 1983	Technical cooperation
May 1984	Protocol on S&T cooperation
May 1984	Memorandum of understanding on cooperation in nuclear energy
Aug 1984	Cooperative use of nuclear energy
Oct 1984	Peaceful use of nuclear energy cooperation

Bulgaria

May 1978	Extension of scientific and technical cooperation agreement of 1955
Sep 1978	Protocol of 16th bilateral session on S&T cooperation
Nov 1979	Protocol of 17th bilateral session on S&T cooperation
Dec 1980	Protocol of 18th bilateral session on S&T cooperation
Sep 1981	Protocol of 19th bilateral session on S&T cooperation
Sep 1982	Protocol of 20th bilateral session on S&T cooperation
Sep 1983	Protocol of 21st bilateral session on S&T cooperation
Sep 1984	Economic and technical cooperation
Nov 1984	Protocol of 22nd bilateral session on S&T cooperation
Aug 1985	Protocol of 23rd bilateral session on S&T cooperation
Sep 1985	S&T, economic and trade cooperation

Burkina

Nov 1984	Economic and technical cooperation

Burma

Jul 1979	Economic and technical cooperation
Jul 1980	Protocol on economic and technical cooperation
Jun 1984	Economic and technical cooperation

Burundi

Mar 1979	Economic and technical cooperation

Cape Verde

Jul 1980	Protocol on economic and technical cooperation

Central African Republic

Jul 1983	Economic and technical cooperation

Chad

Sep 1978	Protocol on economic and technical cooperation
Jul 1983	Protocol on economic and technical cooperation

Chile

Oct 1980	S&T cooperation

Colombia

Dec 1981	S&T cooperation

Congo

Aug 1979	Protocol on economic and technical cooperation
Jul 1980	Economic and technical cooperation
Nov 1982	Two protocols on economic and technical cooperation
Feb 1984	Economic, trade, and technical cooperation

Cuba

Aug 1984	Trade, cultural, and technical cooperation

Cyprus

Jun 1984	Economic and S&T cooperation

Czechoslovakia

Dec 1978	Protocol on S&T cooperation
Sep 1980	Protocol of 22nd session of bilateral committee on S&T cooperation
Sep 1981	Protocol of 23rd session of bilateral committee on S&T cooperation
Jul 1983	Protocol on economic and technological cooperation
Jul 1984	Economic and S&T cooperation
Oct 1984	Agreement on S&T projects
Dec 1985	Protocol on S&T cooperation
May 1986	S&T agreement

Denmark

Sep 1979	Economic and technical cooperation
Oct 1981	Educational, scientific, and cultural cooperation
Apr 1985	Protocol on S&T cooperation

Djibouti

Dec 1979	Economic and technical cooperation

Ecuador

May 1984	Economic and technical cooperation
May 1985	Protocol on economic cooperation

Egypt

Dec 1979	S&T cooperation
Apr 1983	Extension of S&T cooperation

Equatorial Guinea

Aug 1984	Economic and technical cooperation

Ethiopia

Apr 1984	Protocols on economic and technical cooperation

Finland

May 1979	Economic and S&T cooperation
Sep 1980	Protocol of first session of joint committee on economic and S&T cooperation

France

Jan 1978	S&T cooperation
Jun 1978	S&T cooperation between the Chinese Institute of Petrochemistry and the French Petrochemistry Institute

Oct 1978	Supplemental protocol for S&T exchange, also scientific cooperation between Chinese Academy of Sciences (CAS) and the French State Center of Science and Research
Jan 1979	Three-year scientific cooperation on basic research between the CAS and the French Atomic Energy Commission
May 1979	S&T cooperation in metrology
Dec 1979	Geological and S&T cooperation
Dec 1979	Protocol on S&T cooperation
Jul 1981	Cooperation between Biological Department of CAS and the French National Institute of Health and Medical Research
Nov 1982	Civil application of nuclear cooperation
Jun 1983	Expansion of S&T cooperation 1983-84
Apr 1984	Signed minutes for S&T cooperation
Nov 1985	Minutes of S&T cooperation talks
May 1986	Nuclear safety agreement

Gabon

Dec 1983	Protocol on economic and technical cooperation

East Germany

Jun 1983	Posts and telecommunications cooperation
Dec 1983	Protocol on S&T for 1984-85
Apr 1985	Protocol on S&T cooperation
Apr 1985	Cooperation between SSTC and GDR Ministry of Technology
Nov 1985	Economic S&T cooperation
May 1986	Protocol on S&T cooperation

West Germany

Sep 1978	Scientific cooperation between CAS and the German Max Planck Society
Oct 1978	S&T cooperation
May 1979	Cooperation between bilateral standardization institutes
Jun 1979	Protocol on S&T cooperation between CAS and Fraunhofer Society
Jun 1979	Cooperation in geological S&T
Nov 1979	Protocol on scientific cooperation
Sep 1981	Three-year cooperation between the CAS and the German Max Planck Society
Nov 1981	S&T and agricultural cooperation
Mar 1984	Space, S&T cooperation
May 1984	Peaceful use of nuclear energy
May 1984	Scientific and cultural cooperation 1984-85
Jul 1984	Summary of fourth meeting on S&T cooperation
Sep 1984	Protocol on economic and scientific cooperation
Feb 1986	Nuclear cooperation agreement
May 1986	S&T cooperation

Greece

Nov 1979	S&T cooperation
Jun 1983	Economic and technical cooperation

Guinea

Aug 1984	Economic and technical cooperation

Hungary

Nov 1978	Protocol of 18th bilateral session on S&T cooperation
Sep 1980	Protocol of 19th bilateral session on S&T cooperation
Oct 1981	Protocol of 20th bilateral session on S&T cooperation
Dec 1982	Protocol of 21st bilateral session on S&T cooperation
Dec 1983	Protocol of 22nd bilateral session on S&T cooperation
Apr 1984	Cooperation between Association of Hungarian Technical and Natural Scientific Societies and Chinese Academy of Space Technology
Jun 1984	S&T cooperation; establishment of bilateral committee for economic and S&T cooperation
Aug 1984	Protocol of 23rd session of the bilateral commission for S&T cooperation
Oct 1984	Executive program on scientific, educational and cultural cooperation 1985-86
Nov 1984	Public health and medical science cooperation
Jan 1986	S&T cooperation

Iran

Sep 1983	Cultural, S&T cooperation
Mar 1985	Protocol of joint committee on economy, trade, and S&T

Iraq

May 1981	Economic and technical cooperation

Jun 1983	Protocol of first session of bilateral trade exchange, technical, and economic cooperation
Apr 1986	Economic and technical cooperation

Italy

Oct 1978	S&T cooperation
May 1979	Scientific cooperation between the CAS and the Italian Research Committee
Oct 1979	Program of cultural and S&T cooperation 1980-81
May 1980	Protocol on S&T cooperation for peaceful uses of nuclear energy
Nov 1981	S&T and agricultural protocol for 1982
Nov 1983	Cooperation program on science and technology

Japan

Dec 1979	Bilateral cultural, educational, and scientific exchanges
May 1980	Expansion of bilateral S&T cooperation
Sep 1981	Nuclear cooperation and exchanges of experts and engineers, nuclear seminars and conferences
Mar 1984	S&T cooperation between Mitsubishi and China S&T Exchange Center
May 1984	Cooperation between Japanese Nuclear Fuel Development Corporation and the Uranium Geology Bureau of the Chinese Ministry of Nuclear Industry
Jul 1985	Nuclear cooperation agreement
Nov 1985	S&T cooperation

Kenya

Sep 1980	Economic and technical cooperation

Lesotho

May 1983	Economic and technical cooperation

Liberia

Jun 1978	Economic and technical cooperation

Libya

Oct 1982	Bilateral economic, trade, and S&T cooperation

Madagascar

Oct 1985	Agreement on economic and technological cooperation

Maldives

Aug 1981	Economic and technical cooperation
Oct 1984	Economic and technical cooperation

Mali

May 1979	Protocol on economic and technical cooperation
Dec 1984	Economic and technical cooperation

Mauritania

May 1980	Economic and technical cooperation

Mauritius

May 1983	Establishment of a bilateral joint commission for economic and technical cooperation

Mexico

Mar 1979	Protocol of the fourth bilateral session on S&T cooperation
Sep 1983	Summary of minutes on technology cooperation

Mozambique

May 1978	Economic and technical cooperation
Jul 1984	Economic and technical cooperation

Nepal

Jan 1982	Economic and technical cooperation

Netherlands

Oct 1980	Economic and technical cooperation

Nigeria

Mar 1981	Economic and S&T cooperation
Oct 1981	Protocols on economic and technical cooperation

North Korea

Jun 1978	Protocol of meeting on S&T cooperation
Jun 1978	Cooperation in hydrological work between Chinese Ministry of Water Conservancy and Electric Power and the Korean Meteorological and Hydrographical Bureau

Oct 1978	Scientific cooperation between the Chinese and Korean Academies of Science for 1979-80
Oct 1979	Protocol of 19th bilateral session on S&T cooperation
Aug 1980	Protocol of 20th bilateral session on S&T cooperation
Dec 1980	Scientific cooperation between CAS and the Korean Academy of Sciences for 1981-82
Jun 1981	Protocol on teaching scientific research
Nov 1981	Protocol of 21st bilateral session on S&T cooperation
Oct 1982	Protocol of 22nd bilateral session on S&T cooperation
Jun 1983	Protocol of 23rd bilateral session on S&T cooperation
Jun 1984	Protocol of 24th bilateral session on S&T cooperation
Sep 1984	Plan on exchange and cooperation in seismological sciences and technology 1985-86
Dec 1984	Scientific cooperation 1985-86
Jun 1985	Protocol of 25th bilateral session on S&T cooperation

Norway

May 1979	Scientific cooperation for 1979-80
May 1980	Economic, industrial, and technical cooperation
Sep 1980	Economic, industrial, and technical cooperation
Oct 1980	Program on cultural, education, and scientific cooperation 1981-83
Jun 1985	Signed minutes of talks on technology

Pakistan

Jul 1978	Protocol on S&T cooperation
May 1980	Protocol on S&T cooperation 1980-81
Dec 1980	Protocol on economic and technical cooperation
Dec 1981	Protocol of 4th bilateral session on S&T cooperation
Oct 1982	Establishment of bilateral committee for economic and S&T cooperation
Feb 1986	Protocol on S&T cooperation

Papua New Guinea

Jun 1983	Technical cooperation

Philippines

Mar 1978	S&T cooperation
Oct 1978	Protocol on S&T cooperation
Jul 1979	Economic and technical cooperation
Dec 1980	Protocol of 3rd bilateral session on S&T cooperation
Nov 1981	Protocol of 4th bilateral session on S&T cooperation
Dec 1982	Protocol of 5th bilateral session on S&T cooperation
Jan 1984	Protocol of 6th bilateral session on S&T cooperation
Mar 1985	Protocol of 7th bilateral session on S&T cooperation

Poland

Oct 1979	Protocol on S&T cooperation
Dec 1980	Protocol on S&T cooperation 1981
Nov 1981	Protocol on S&T cooperation 1982
Dec 1982	Protocol of 15th bilateral session on S&T cooperation
Oct 1983	Protocol of 16th bilateral session on S&T cooperation
Jun 1984	Economic and technical cooperation
Sep 1984	Protocol of 17th bilateral session on S&T cooperation
Apr 1985	Summary of first meeting of Sino-Polish Commission for Economic, Trade, and S&T cooperation
Oct 1985	Protocol on S&T cooperation
Nov 1985	Protocol on trade exchanges, economic and technical cooperation
May 1986	Protocol on S&T cooperation

Portugal

Apr 1982	Cultural and S&T cooperation
Oct 1982	Economic and technical cooperation

Romania

May 1978	Economic and technical cooperation
Aug 1978	Establishment of a bilateral committee on economic and technical cooperation, also protocols involving S&T
Nov 1978	Protocol of 19th bilateral session on S&T cooperation
May 1979	Protocol of 1st bilateral meeting of economic and S&T cooperation
May 1980	Scientific cooperation between the CAS and the Romanian National Council for S&T 1980-82

May 1980	Protocol of 2nd bilateral session on economic and S&T cooperation
May 1981	S&T cooperation
Nov 1981	Protocol of 3rd bilateral session on economic and S&T cooperation
Nov 1981	Protocol of 4th bilateral session on economic and S&T cooperation
Apr 1982	Expansion on economic and S&T cooperation
May 1983	Protocol of 5th bilateral session on S&T cooperation
Apr 1984	Scientific cooperation between the CAS and the Academy of Romania
Aug 1985	Protocol of 6th bilateral session on economic and S&T cooperation
May 1986	Protocol on S&T cooperation

Rawanda

Jun 1978	Economic and technical cooperation
May 1983	Cultural and scientific cooperation

Sao Tome and Principe

Jul 1983	Economic and technological cooperation

Seychelles

May 1978	Economic and technical cooperation
Apr 1983	S&T cooperation

Sierra Leone

Apr 1985	Economic and technical cooperation
Feb 1986	Economic and technical cooperation

Somalia

Apr 1978	Economic and technical cooperation
Mar 1986	Economic and S&T cooperation

Soviet Union

Dec 1983	Improvement of joint meteorological operations
Dec 1984	Economic and S&T cooperation
Jan 1985	Economic and S&T cooperation
Mar 1986	Economic and S&T cooperation

Spain

Apr 1981	Five-year cultural, educational, and scientific cooperation

Sri Lanka

Jan 1980	Economic and technical cooperation
May 1984	Establishment of a bilateral committee for economic and S&T cooperation
Aug 1984	Protocol on economic and technical cooperation
Mar 1986	Economic and technical cooperation

Sweden

Oct 1978	S&T cooperation between CAS and the Royal Swedish Academy of Engineering Sciences
Dec 1978	Ten year cooperation in industry, science and technology
Mar 1979	Scientific cooperation between the CAS and the Royal Swedish Academy
Oct 1981	Protocol on S&T cooperation
Oct 1984	Protocol of 5th session on joint industrial and S&T cooperation
Mar 1986	Protocol of 6th session on S&T cooperation

Tanzania

Sep 1978	Protocol on economic and technical cooperation
Mar 1980	Protocol on economic and technical cooperation
Aug 1983	Technical cooperation

Thailand

Mar 1978	S&T cooperation
Aug 1978	S&T cooperation
Nov 1978	Plan for S&T cooperation for 1978-79

Tunisia

Dec 1983	Establishment of bilateral commission for economic and technical cooperation
Oct 1984	Economic and technical cooperation

Turkey

Dec 1981	Economic, industrial, and technical cooperation
Mar 1986	Economic and technical cooperation

United Arab Emirates

Nov 1985	Agreement on economic trade and technical cooperation

United Kingdom

Nov 1978	Scientific cooperation between the CAS and the British Royal Society

Nov 1978	S&T cooperation
Nov 1979	Railway and S&T cooperation
Dec 1981	Protocol for cooperation in S&T
Mar 1984	S&T cooperation between the CAS and the British Royal Society

United Nations

Jul 1980	Cooperation between the CAS and United Nations University
May 1983	Extension of scientific cooperation between CAS and United Nations University

United States

Oct 1978	Understanding on student exchanges
Nov 1978	Understanding on agricultural exchanges
Dec 1978	Agreement on space technology
Jan 1979	S&T agreement; implementing accord on high-energy physics
Apr 1979	Agreement for academic exchange to cooperate in science
May 1979	Protocol between SSTC and the US Department of Commerce for cooperation in S&T management; protocol on atmospheric S&T; protocol on metrology and standards
Jun 1979	S&T cooperation in medicine and public health between Department of Health, Education and Welfare, and Chinese Ministry of Public Health
Aug 1979	Protocol on hydroelectric power and related resources management
Jan 1980	Protocol on Earth sciences and on earthquake studies
Jan 1980	Science and technical cooperation
Feb 1980	Environmental protection S&T cooperation
Oct 1980	Cooperation between Chinese Nuclear Society and American Nuclear Society
Nov 1980	Protocol on S&T cooperation in medicine and public health
Dec 1980	Protocol on basic sciences
Dec 1980	Scientific cooperation between CAS and Smithsonian
Oct 1981	Protocol on nuclear safety matters; protocol on surface water hydrology
May 1983	Nuclear physics, biomedical transportation, aeronautical (four agreements)
Jun 1983	Exchange of technical experts and information
Jan 1984	Industrial and technical cooperation accord
Apr 1984	Cooperation agreement on nuclear energy
Apr 1984	Industrial S&T; S&T cooperation (two agreements)
May 1984	Work programs for cooperation in metallurgical, telecommunications, and electronics industries
May 1984	Scientific and nuclear cooperation
Jul 1984	Work program for industrial and technical cooperation in the aerospace industry
Sep 1984	Agreement with Georgia Tech for joint venture in research and technology
Oct 1984	Cooperative program for high-energy physics
Jan 1985	Agreement extending January 1980 Earth sciences agreements
May 1985	Extension of June 1979 medicine and public health agreement
Jul 1985	Protocol on S&T cooperation (four agreements)

Vanuatu

May 1983	Protocol on economic and technical cooperation

Venezuela

Nov 1981	S&T cooperation

Western Samoa

Jun 1980	Economic and technical cooperation

South Yemen

Apr 1978	Economic and technical cooperation

Yugoslavia

Aug 1978	Establishment of a bilateral commission on economic and S&T cooperation and a long-term agreement on S&T cooperation
Sep 1978	Scientific cooperation between CAS and the Yugoslav Commission of Academies and Sciences and Arts
Feb 1979	Protocol on S&T cooperation 1979
Mar 1979	S&T cooperation and protocol for 1st bilateral session of committee for economic and S&T cooperation

Apr 1979	Cooperation in research of high voltage switches
Mar 1980	Protocol on 2nd bilateral session on economic and S&T cooperation
Apr 1980	Cooperation for peaceful use of atomic energy; exchange of S&T information
Oct 1981	Protocol on S&T cooperation 1981-82
Mar 1983	Protocol of 3rd bilateral session on economic and S&T cooperation
Sep 1984	Protocol of 4th bilateral session on economic and S&T cooperation

Zaire

Dec 1979	Technical cooperation
Nov 1985	Protocol on S&T cooperation 1985-86

Zambia

Jan 1979	S&T cooperation
Apr 1980	Economic and technical cooperation

Zimbabwe

Sep 1980	Economic and technical cooperation
Sep 1981	Protocol on economic and technical cooperation
Jan 1983	Economic and technical cooperation
Aug 1985	Agreement on economic and technical cooperation

Total: 327 agreements, 86 countries (not including the United Nations)

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